438539 122795

REVIEW OF

INTEGRATED FISH FARMING (CHINA)

PROJECT

A REPORT TO

INTERNATIONAL DEVELOPMENT
RESEARCH CENTRE
CANADA

September 1, 1988

DR. JACK A. MATHIAS

FRESHWATER INSTITUTE
DEPARTMENT OF
FISHERIES AND OCEANS
CANADA

TABLE OF CONTENTS

I. REVIEW SUMMARY

A. Research Manuscripts

Six unpublished reports associated with the IDRC-sponsored Pond Integrated Fish Farming project are acceptable for publication in an international journal after English revision and statistical treatment.

B. Pond Dynamics Projects

The research in pond dynamics is of good quality. The work in most projects has been replicated in two years, and can be considered sufficient for a primary publication in an international journal.

Specific suggestions about methodology are recommended in this report for the continuation of research in each project.

C. Staff Upgrading

English language training is a priority, and should be undertaken by sending scientists on study leave to English-speaking laboratories for technical training.

Training in statistical analysis is also a priority, but might better be carried out by arranging for two, one-month statistics courses to be taught at Wuxi.

Training in specific technical areas is a lesser priority, but would be useful to introduce scientists to new techniques and approaches to ecosystem studies. This training is best done by foriegn study leave.

Specific areas for further technical training were identified. These are:

a) quantitative analysis in aquaculture
b) microbiology
c) limnology
d) microcomputer technology

D. Equipment

A requirement for several pieces of major equipment is identified. The equipment is for data analysis and for the measurement of primary productivity, water circulation and the energy content of manure particles.

A number of expendable research supplies are identified which are not available or are difficult to obtain in China.

E. New Research Directions

The experimental results from two years of pond dynamics research is organized into a series of twelve hypotheses which form a basis for suggested future research.

The twelve hypotheses are grouped into three multi-disciplinary research projects. These are:

a) studies of suspended organic matter
b) studies of food and feeding of fishes
c) studies of physical water mixing processes

in integrated fish ponds. The projects are designed to focus emphasis upon the important processes which determine fish productivity.

The importance of integration of the pond dynamics research with the bio-economic survey is recognized. A mechanism is required which will link pond research to problems identified by fish farmers, and which will encourage the development of new technology under actual farm conditions.

II. INTRODUCTION

In 1981, the government of the People's Republic of China, with assistance from FAO/UNDP, established the Asian-Pacific Regional Research and Training Centre for Integrated Fish Farming (RLCC), at Wuxi, Jiangsu Province. Its major functions are to implement research, training and information programs in integrated fish farming aimed at transferring the technology nationally and regionally.

In 1986, the RLCC embarked on a research program on integrated fish farming, assisted by IDRC. The general objective of this research was to:

-establish the scientific criteria for successful fish production in manure-loaded ponds, in order to facilitate the adaptation and implementation of integrated fish, livestock, and crop farming technology in areas with different climatic and socio-economic conditions.

The more specific objectives of the IDRC-sponsored project (Integrated Fish Farming, China) were:

-To improve the scientific capability of the RLCC staff.

-To study the inter-relationship between fish yield and the following factors (pond dynamics):

- -frequency of animal manure application
- -different types of animal manure
- -fresh and fermented animal manure
- -depth of ponds
- -fresh and composted green manure
- -fish stocking density and stocking ratios

Twenty-four months after the inception of this project, I travelled to Wuxi, China to review its progress with the following terms of reference:

-To review the research progress to date of the IDRC-supported project, by project objectives, and to advise on the methodologies used, and

-To review and assist in the revision of research manuscripts now being produced and assist project staff to attempt to get these published in international peer reviewed journals.

From April 21 to May 4, 1988, I reviewed research manuscripts, interviewed research staff, and discussed research design with project leaders. The following report documents my observations.

III. PROJECT REVIEW

A. REVIEW OF RESEARCH MANUSCRIPTS

The following manuscripts were reviewed at the Freshwater Research and Training Centre, Wuxi, and discussed with project scientists.

Of the sixteen manuscripts reviewed, two were preliminary reports of 1986 data, and were combined with 1987 data in subsequent reports. Three manuscripts dealt with the Bio-economic survey. Of the remaining eleven manuscripts, four had already been published, (three in the First Asian Fisheries Forum, and one in Aquaculture Journal), and one had been accepted by Aquaculture. The remaining six unpublished reports were associated with the IDRC-sponsored Pond Dynamics research project, and are acceptable for publication after English revision and statistical treatment.

MANUSCRIPT	STATUS
Preliminary studies on the effect of frequencies of manure application upon fish yield. 1987. Zhu, Y., Y. Yang, J. Wan and D. Hua.	- Includes only the 1985 data. - To be combined with results of later studies.
Studies on the interrelations between frequencies of application and fish yield in ponds with silver carp as major species. 1988. Zhu, Y., Y. Yang, J. Wan and D. Hua.	- Combination of 1986, 1986 and 1987 data. - Requires statistical analysis. - Is being revised while Mme. Zhu is in Canada. - Will be submitted to journal in 1988.
The effects of different animal manures on ecological factors and fish yields in fish ponds. 1984. Fang, Y., X. guo, J. Wang, Y. Yang, Y, Yang, and Z. Liu.	- One half of the data is published in the First Asian Fisheries Forum. - The other half should be published. - Requires statistical analysis.
Studies on the effects of fresh & fermented pig manure on fish production. 1987. Yang, Y., Y. Zhu, D. Hua, and J. Wan.	- Constitutes data taken in 1986. - Will be combined with subsequent data.
Re-observations on the effects of fresh and fermented pig manure on fish production. 1988. Yang, Y., Y. Zhu, D. Hua and J. Wan.	- Combines data from 1986 and 1987. - Requires statistical analysis. - Should be published after English revision.
Observational study of the effects of several fresh & compost/fermented green manure upon fish farming. 1987. Shan, J. and S. Wu.	- Constitutes 1986 data. - Cannot be published without 1987 data because of lack of replication within one year. - Requires statistical analysis. - Should be published after English revision.

Studies on the ecological effects of varying the size of fish ponds loaded with manures and feeds. 1987. Zhang, F.L., Y. Zhu, and X.Y. Zhou.	- Published in Aquaculture journal.
Comparative studies of ecosystems of the fish ponds with different depth. 1986. Zhu, Y., Y. Yang, L.F. Zhang, X. Zhou and R. Yu.	- Contains 1986 data. Results are very important for understanding pond dynamics. - Should be repeated in 1988, because only 4 ponds were studied, and only one was replicated. - Requires statistical analysis.
The biological basis and the optimal stocking ratio of polyculture with grass carp as dominant species and with filter-feeding and omnivorous fish brought up along. 1986. Yang, H.Z., Y.X. Fang and Z.Y. Liu.	- Submitted to Aquaculture journal in 1987. - Editorial changes have been requested. - Requires statistical analysis.
Preliminary studies on the effects of animal manure on bacterial diseases of fish. 1986. Ding, J.Y,. X.Z. Guo, X.Z. Fang, M.Z. Liu and W.Y. Chang.	- The degree of variation between repeated samples must be presented, as well as variation among replicate samples. - Requires statistical analysis.
Effects of different animal manures on fish farming. 1986. Fang, Y.X., X.Z. Guo, J.K. Wang, X.Z. Fang and Z.Y. Liu.	- Published in the First Asian Fisheries Forum, 1986.
A preliminary study on sources of fish growth in manured ponds using delta C analysis. 1986. Guo, X.Z., Y.X. Fang, J.K. Wang, X.Z. Fang and Z.Y. Liu.	- Published in the First Asian Fisheries Forum, 1986.

Observations on feeding habits of fish in ponds receiving green and animal manures in Wuxi, People's Republic of China. 1985. Shan, J., L. Chang, X. Gua, Y. Fang, Y. Zhu, X. Chor, F. Zhou, and G.L. Schroeder.	- Published in Aqaculture journal, 1985.
Preliminary report on surveys of economic benefits of integrated fish farming in China. 1987(?). Bioeconomic Modelling Research Group, Freshwater Fisheries Research Centre, Wuxi.	- Not for publication. - Outline of some of the approaches taken to the economic survey of integrated fish farming, with a few examples.
A synopsis of modeling research on bioeconomics of the integrated piscicultur in China. 1988 (?). Bioeconomic Modelling Research Group, Freshwater Fisheries Research	- Not for publication. - Lists the objectives, methodology, major participants and funding for the research.
RLCC progress achieved in the studies on theoory of high yielding integrated fish farming in China. Report on the results of IDRC-assisted research project (April 1, 1985-October 30, 1987). 1988. (anon).	- Not for publication. - Five page summary of main activities and results of the IDRC project 3-P-85-0065.

The objective of reviewing research manuscripts was completed. General suggestions regarding future research directions, based on these manucripts, were discussed with project staff.

The objective of assisting with revision of research manuscripts was not attempted, except in the most general way. It is estimated that revision and statistical analysis required for each manuscript would take approximately 4-5 working days, given that discussion with the author would procede through an interpreter. Revision of Mrs. Zhu Yun's manuscript will procede in Canada, and suggestions have been made for Mrs. Zhu to assist with the revision of other manuscripts while she is in Canada.

Several manuscripts associated with the Bio-economic Survey of Integrated Fish Farms were reviewed, and discussions were held with Mr. Chen Guan Seng, Head, Economics Department, regarding the survey. Although a review of this project is outside the terms of reference of this report, the importance of integration between the Bioeconomic Survey and the Pond Dynamic Research is clearly implied in the objectives of the pond dynamics research (see "Introduction", above).

B. REVIEW OF POND DYNAMICS PROJECTS

The pond dynamics research projects were reviewed by:

a) reading the english versions of each research report.
b) interviews with principal scientists involved in the research.
c) inspection of research facilities such as ponds, research laboratories and equipment.
d) a general discussion involving all principal scientists as well as the research directors.

The results of these interviews are dicussed below.

1. FREQUENCY OF MANURE APPLICATION

This research is complete, having been repeated over two years and replicated within each year. The results show that when the amount of manure applied to a pond is held constant, the total fish yield (contributed mainly by silver carp) increases as the frequency of manure application is increased.

The results should be submitted to an international journal for publication. Mme. Zhu Yun is now working on the analysis and re-writing of these research results in Canada.

This research project should be pursued in more depth in the future in order elucidate the biological mechanisms which produced the observed results. If the work is continued, then it is recommended that:

a) the experimental design should remain the same except that the manure applications should be made at one/7 days, one/5 days, one/two days and one/1day (see Fig. 2). The one/10 days and one/30 days applications could be omitted.

c) the inorganic nutrient addition could be omitted.

d) more detailed attention should be paid to measurment of the characteristics of the manure once it is in the water, and how this changes with time. Some suggestions for more detailed measurements are:

1) measure the density of manure particles as it varies with time; i.e. every hour for the first 6 hours after application, then every 6 hours for the next 18 hours, and every day thereafter (see Figs. 3 and 4).

2) measure the sinking rate of seston particles, over the same time intervals as in 1, above).

3) measure total seston weight, zooplankton weight, phytoplankton weight. Measure ash weights of all three.

4) measure C.O.D. and C:N ratio of seston particles.

5) examine manure particles from the pond under the electron microscope to discover differences in structure.

2. DIFFERENT TYPES OF ANIMAL MANURES

This project has demonstrated clear differences in the fish yield derived from different types of animal manure. The results should be submitted to an international journal for publication.

In submitting for publication, attention should be paid to statistical validation of the differences between manures. Results should be restricted to the 1983 data, as the 1984 data have been published in the First Asian Fisheries Forum.

Further research on this topic should adress the question of why certain manures outperform others. As in project 1, the basic underlying mechanisms which produced the observed result have not been elucidated.

The investigators suggest that the quality of the food is important, rather than the amount of seston particles generated in the water. This should be carefully checked with measurements made on the suspended manure after application as suggested for project 1.

If the quality of the food is important, the investigators should make careful measurements of proximate composition of the manure, before application, as it varies with time throughout the experiment, so that the total energy input to the ponds can be calculated for each type of manure.

3. FRESH VS FERMENTED ANIMAL MANURES

This project is completed, having been repeated in 1986 and 1987 and replicated. The results have demonstrated that fresh animal manure produces a higher fish yield than fermented manure. The work should be published in an international journal.

Before publication, the data should be subjected to statistical analysis to validate the differences found between the various experiemental treatments.

This initial work suggests that the quality of fresh manure, or the availability of it to the fish once it's in the water, is superior to that of fermented manure. Further work should focus upon the reasons for this. Detailed study should be made of the changes in nutritional quality as manures are fermented. The Fish Nutrition Section of the department of Integrated Fish Farming could give guidance on the required methodology.

Secondly, attempts should be made to measure the characterisitcs of the fermented and fresh manure after it is put into the ponds. Characteristics such as particle density, sinking rate and nutritional quality should be examined as outlined in project 1.

Finally, the oxygen content of the pond water should be measured at all depths, particularly over the first 24 hours following manure application, to determine whether fresh manure addition is associated with water quality problems. Common farm practice should be used to guide this work, since apparently almost all fish farmers prefer to use fermented manure rather than fresh.

4. FRESH VS COMPOSTED PLANT MANURES

I reviewed work done in 1986, as work done in 1987 was still in the process of being written up. This work should be considered complete and the results of the two years should be combined and published in an international journal.

Statistical analysis should be applied to the data using analysis of variance, to determine whether the differences between fresh and composted, and between the different types of green material, are true differences, or only a result of chance.

Some assistance will be necessary with the statistical analysis. I suggest that as part of Mme. Zhu's trainning in statistical procedures, that she work on Mr. Shan Jian's data set while she is in Canada. In this way, she will be able to work on a data set with which she is familiar, while Mr. Shan Jian will recieve assistance in the statistical analysis.

This study indicates that fresh green material used as a manure produces higher fish yields, particularly of filter-feeding fishes, than composted material. Further work should focus upon the reasons for this result. Detailed analysis should be made of the changes in nutritional quality of green material as it is composted. The Fish Nutrition Section of the Integrated Fish Farming Department could give guidance and assistance with the methodology. The Delta-C analysis has been completed in the present study, and could be omitted in future work.

If this study is repeated in 1988, the experimental design used in 1986 should be repeated exactly, so far as is possible. The reason for this is that some of the experimental treatments used in 1986 were not replicated, and work done in 1987 or 1988 could be considered replicates (for statistical analysis) of the 1986 work. Statistical replication of the different applications is particularly important in this study because the differences between "fresh and composted" material, and between "different green materials", are not very large.

5. POND SIZE AND POND DEPTH

This study has given a particularly useful insight into energy pathways within the integrated fish farming ponds. As the size of the pond increased by each mu, the yield of silver carp increased by 15 kg per mu even though all inputs per mu remained constant. This suggests that physical processes are important to increase fish yield, particularly the influence of the wind in bringing about increased circulation of pond water.

Secondly, when the water depth in the ponds was increased without changing the area of the pond, more energy went into filter feeding fishes and less energy was lost to the pond humus. This is an important result for fish farmers, because one of the major problems they face in integrated fish farming is the continued build-up of humus (sediment) at the bottom of the fish ponds.

This result, because of its significance, should be carefully confirmed in 1988 if possible, using six ponds in which the ratio of "water volume : humus area" varies regularly between 1.0 and 3.0. When completed, these results should be combined with selected data from the "pond size" study (most of the "pond size" study has been published already in Aquaculture Journal), and written up for publication in an international journal.

Suggestions for presentation of these data are given in Figure 9.

6. FISH STOCKING RATIOS

This study has been replicated twice and repeated in 1985 and 1986. The results give useful insights into pond dynamics. For example, the 1985 results show that as the weight ratio of "grass carp : filter-feeders" increased, the yield of filter-feeding fishes increased. This result was surprising because the food input to the grass carp, (which was the only food input to the ponds) was held constant.

It is not clear whether the ratio of "10 kg grass carp : 2 kg filter-feeders" gives the highest possible yield, since higher ratios were not tested. Figure 5 suggests that yields could go higher, if the "grass carp : filter-feeding fish" ration is increased.

It is recommended that this study be continued, using the following ratios of grass carp (weight) to filter-feeding fishes:

4.0: 10 kg grass carp : 2.5 kg filter-feeders

5.0: 10 kg grass carp : 2.0 kg filter-feeders

6.0: 10 kg grass carp : 1.7 kg filter-feeders

7.5: 10 kg grass carp : 1.3 kg filter-feeders

using two replicates per ratio. The Delta-C analysis has been completed for this experiment in 1986, and can be omitted in further work.

Other measurements which would be important in this experiment are: primary productivity, pond depth, pond area, pond humus area and pond humus volume. The results of further work should be combined with the earlier work and submitted to an international journal for publication. If the first two years of data have already been submitted, then the work should be continued in order to completely define the relationship between species ratio and fish yield. This would constitute a second publication.

7. GENERAL COMMENTS

In planning all new research, it is essential that researchers consider the statistical analyses which will be applied to the data. All experimental treatments must be replicated, and all sampling must be done in such a way that the variability of average measurement values can be estimated. This is an essential requirement for acceptance of data in international journals. Also, data which is highly variable, or which doesn't seem to fit an established idea, should not be discarded. These data are often very important in identifying new research directions, and suggesting alternative hypotheses.

One of the major energy "sinks" in the pond ecosystem, which if often unutilized and a major problem to fish farmers, is the pond humus. Therefore it is strongly recommended that researchers consider it as an important "yield" from the pond, and measure it accurately at the end of an experiment, just as they do for fish yield. The important parameters to measure are pond depth and area, and after the pond is completely drained, humus area and humus volume.

One of the most important energy "sources" in fish ponds is primary productivity. Therefore, measures of primary productivity should always be included as one of the inputs, when other inputs such as manures or grasses are added to a pond. Measures of primary productivity are time consuming, and therefore difficult to measure over a large number of ponds. However, new techniques developed at the Freshwater Institute by Dr. E. Fee now make it possible to measure primary productivity on a very large number of ponds at the same time. These techniques could be transferred to the study of integrated fish farming.

Consideration should be given to a more exact characterization of manure inputs, than a simple "dry weight " of chicken, pig, duck, and cow manure. Some characteristics which might be considered, in order of inferred importance, are:

a) energy content (dry weight basis)
b) distribution of particle sizes
c) particle density (no./l)
d) settling rate through the water
e) nutrient content (nitrogen and phosphorus)

For example, particles from pig manure have been described as more uniform, smaller, and like the "roots of a feather", in comparison with particles from fresh pig manure, which has a more flocculent appearance.

The preparation of manure fertilizers should be standardized, or at least carefully documented. For example, fermentation of manure for a "standard" two week period may give very different quality when carried out at 30 C and at 15 C.

C. STAFF UPGRADING

The quality of scientific research carried out by the staff of RLCC under the initial IDRC research support grant attests to the capability of the research team. However, in order for these scientists to play a leadership role in world-class fisheries research, they should consider staff training in three major areas: (1) English language training, (2) Quantitative analysis, and (3) Technological disciplines relevant to aquatic ecology.

1. ENGLISH LANGUAGE TRAINING.

The scientific productivity of the pond dynamics research staff is high, but the rate of introduction of their work into the world literature is limited by difficulty with the English language, and by contacts with English-speaking scientists.

The quickest remedy for this problem is to send researchers to work for extended periods of time (6 months to one year) in laboratories in English-speaking countries. However, the importance of English language study by Chinese scientists in China should not be underestimated. The progress which a visiting scientist can make while on study leave in an English-speaking country is directly proportional to their command of English before starting.

One of the objectives of these study periods should be to write and submit at least one paper to an English scientific journal. In this way, familiarization with western publishing styles and formats could be gained, at the same time as familiarization with English language and technical terminology. In addition, working contacts with western scientists would provide a mechanism for continuing assistance with editing in the future.

Working contacts with scientists outside China would also lead to broader use of the world literature. It is noted that in the publications reviewed under Section III. B. of this report, there are almost no references to scientific papers dealing with the general concepts of trophic ecology or even aquatic ecology. While a deficiency in English language training might explain why western ideas have not been considered, it is not clear why the Russian literature is not cited more frequently, particularly in view of the fact that Russia is a world leader in these areas of science. In any case, researchers should be encouraged to consult the world literature on much general thinking which has been applied to the problems of trophic dynamics and aquatic ecology in other countries.

2. STATISTICAL ANALYSIS.

Ecological research is a relatively imprecise science because of the many factors in any experiment which cannot be controlled by the experimenter. Therefore any quantitative result from an experiment must be interpreted against a background of natural environmental variability. This is generally done using the tools of statistical analysis. While statistical analysis of data is virtually a requirement for pulblication in western scientific journals, it has rarely been used in the papers reviewed under Section III.B. of this report.

This situation can be remedied by introducing statistical analysis training to the researchers at the Freshwater Fisheries Research Centre, either by short-term courses (2-3 months) at Wuxi, or by including statistical training in programs involving Chinese visiting scientists. It should be noted that when statistical training is desired from western universities, it should be oriented towards "data analysis in environmental biology", rather than towards "mathematical statistics".

3. TECHNOLOGY TRAINING

There are several areas of aquatic ecology where researchers at the Freshwater Fisheries Research Centre might benefit from exposure to new technology and alternative techniques. Some examples are the following:

a. Quantitative analysis in aquaculture.

This field is essentially concerned with building mathematical models of processes operative in aquaculture systems. It relies heavily on statistical analysis to derive emperical models from observed data or to compare logical models to experimental data. This approach has a wide applicability to integrated fish farming, because many of the familiar ecological processes in a pond ecosystem can be modelled; for example primary productivity, fish feeding, and water mixing. It is a useful approach, because once the factors which control fish farm productivity can be defined quantitatively, the behaviour of the productivity can be predicted under variable conditions.

b. Microbiology

Microbiology is an important discipline in research on intensively cultivated fish ponds because bacterial processes are so critical in controlling water quality and energy transformation. For example, in the process of breaking down organic material suspended in the water, bacteria enrich these particles by increasing the N:C ratio and increasing their protein content. Also, the activity of aerobic bacteria at the sediment surface and in the water column produces a continual demand for oxygen which can become unbalanced under certain conditions, and lead to oxygen depletion. The Freshwater Institute has a particularly strong research group working on ecological microbiology. Many of their approaches could be applied to integrated fish farming.

c. Limnology

There are a number of areas where limnological principles can be usefully applied to the study of pond dynamics. For example in the areas of nutrient cycling, primary productivity and water mixing. In each of these areas, there have been important advances in the past ten years, both in concepts and in the technology of measurement. Staff at FFRC could take advantage of these new technologies in their studies of fish culture ponds. The Freshwater Institute is particularly strong in limnological research.

d. Computer Technology

Microcomputers are now an accepted and reliable tool for the organization, manipulation and analysis of data, as well as for word-processing. They can greatly increase the productivity of scientists, particularly in the preparation of manuscripts for publication. Once an experiment is completed, almost all of a scientist's work, including drafting, can now be done on a microcomputer. This technology would therefore be most useful to researchers at FFRC in upgrading scientific productivity.

D. EQUIPMENT REQUIREMENTS

The following are major pieces of equipment (>$1,000) which would be required for research. The toatl cost is estimated at approximately US$15,000.

a. bomb calorimeter. -for measuring energy content of suspended materials.

b. Underwater light meter -for collecting data used in primary productivity modelling.

c. Fluorometer and fluorescent dyes. -for measuring the degree of mixing in fish ponds.

d. IBM-compatible microcomputer and commercial software. -for data analysis, modelling work, word processing, and graphics.

e. Temperature monitoring devices. -for continuous monitoring of temperature in fish ponds.

The following items are smaller (>$500) and many are considered to be expendible supplies. Their importance to the project should not be overlooked however, because most of them are impossible, or very difficult to obtain in China.

a. Whatman glass fibre filter papers, pore size nominally 0.45 microns. (not available in China, but necessary for measurement of suspended organic matter.

b. Pipettes, plastic, automatic, variable capacity. There are a large number of these available in Canada, and they replace many of the glass type of pipette. They are much more efficient for pipetting large numbers of samples.

c. Rubber pipette bulbs, three-way. For instances where glass pipettes are used, these are used to control flow.

d. Metal aluminum foil. Difficult to obtain in China.

e. Electrical transformers, from 120 to 220 volts. Difficult to obtain in China.

f. B.O.D. bottles, 300 ml capacity. Difficult to obtain in China.

g. Parafilm paper, a teflon covering used to seal the mouth of reagent and solution bottles. Disposable. Important in China where buildings are open, and dusty conditions are common.

h. Gelman filter paper, organic, pore size 0.45 micron, used for primary productivity measurements.

IV. SUGGESTED RESEARCH DIRECTIONS

The Pond Dynamics research is aimed at understanding the various factors which influence the direction of energy pathways within the fish pond ecosystem. It is thought that this understanding will make possible an increase in fish yields in integrated pond aquaculture systems. It may also make possible the extension of this type of integrated fish farming system into other areas of China or into other countries, without loss of fish yield.

The research carried out from 1986 to 1988 can be considered exploratory in nature. It has served to:

(a) define certain pathways of energy transfer.

(b) identify certain relationships between different types of fish and their food.

(c) emphasize the importance of suspended organic particles in this aquaculture system, and

(d) demonstrate the control of fish production by physical processes such as water circulation and the sinking rates of particles in water.

The ecological concept of an integrated fish pond which emerges from these studies is shown in Figure 1. This simplified version of the major energy pathways in a generalized fish pond is explained below.

There are four general classes of inputs to this pond system (Fig. 1). These are green manures, animal manures, fish feeds and solar energy. Green manures (vegetable material) are generally fed to grass carp, which then excrete finely-divided organic particles which are termed detritus.

Animal manures contribute organic particles, or detritus, directly to the water, and also contribute dissolved nutrients which may be taken up from the water by bacteria and by phytoplankton. Some of the manure sinks directly to the pond bottom where it is attacked by bacteria, and may ultimately be consumed by bottom-feeding fishes, or buried under additional sediment.

Fish feeds, formed from substances such as bean cake, silk workm cocoons, etc., generall sink rapidly to the pond bottom where they may be consumed by the bottom feeding fishes such as common, black and crucian carps.

Solar energy is captured by the phytoplankton which derive energy by photosynthesis. Generally, photosynthesis proceeds at a faster rate if there are more inorganic nutrients such as phosphate and nitrate in the water.

Detritus refers to particles in the water which are organic, but non-living. Detritus may be derived from dead phytoplankton cells, or from the organic particles in manures. It may be colonized by bacteria which feed upon it.

The detritus, bacteria and phytoplankton, taken together, are called the "suspended organic matter". It can be higly variable, both in its make-up and in its quality as a food for fishes. It is fed upon by the zooplankton and by the filter feeding fishes such as silver and bighead carps. The zooplankton can also be fed upon by the bighead carps.

A. DEVELOPMENT OF RESEARCH HYPOTHESES

It is suggested in Figure 1 that one of the most important components of the pond ecosystem is the "suspended organic" matter, first because it is generated by three of the least expensive inputs to the pond, and secondly because it is the major food of the most prodctive fish species in the pond, silver carp.

It is also suggested by Figure 1 that in order to understand the optimal rates for stocking of the various fish species, and for fertilizing with different manures, it is necessary to understand how the growth of the different fish is regulated by the different types of food component.

Finally, Figure 1 suggests that if the basis of the pond food chain is the "suspended organic" material, then physical processes such as the rate of sinking and resuspension of particles in the water must be important in determining whether energy is directed towards the filter-feeding fishes, or towards the pond bottom.

In summary, Figure 1 is a simple paradigm of how the fish pond system works, and serves as a basis for dividing the Pond Dynamics Research into the following three projects:

(a) Suspended Organic Matter.
Characterization of the suspended organic matter in fish ponds, and measurement of the rate of its formation, transformation and utilization.

(b) Food and Feeding of Fishes.
Definition of the rate of food consumption and growth of fishes in relation to their food supply in integrated fish farm ponds.

(c) Physical Processes.
Examination of physical processes, and the control which they exert upon the distribution of fish foods within the ponds.

The following discussion desribes these projects, and suggests several hypotheses around which each project could be organized.

1. STUDIES OF SUSPENDED ORGANIC MATTER

Zhu et al., (1988) show that the yield of filter-feeding fishes and the total fish yield of integrated fish farm ponds is increased if an equivalent amount of pig manure is applied to ponds at daily intervals rather than at weekly intervals (Fig. 2). It is suggested that daily, smaller additions tend to maintain a higher concentratinon of organic particles available in the water as food for silver carp.

HYPOTHESIS #1: Detrital Addition Rate.
-That smaller, more frequent additions of manure lead to higher steady-state concentrations of organic particles which form the food of filter-feeding fishes.

This hypothesis needs to be tested by measuring the density of organic manure particles in the water at closely-spaced intervals after and during manure application. The rate of change in the density of suspended manure particles could be compared with simple models such as a first order exponential decay model (see Figs. 3 and 4) to see if the behaviour of particle density can be predicted.

There is evidence from several of the FFRC studies (particularly those of Mr. Zhang Laifa) that turbulent mixing forces in the pond play an important role to increase the residence time (time that particles remain in suspension) of suspended particles. Priority should be given to obtaining equipment which can be used to measure relativley small turbulent mixing processes, such as a fluorometer for measuring fluorescent dyes. Physical mixing process will be discussed later.

Zhu et al. (1988) also show that the only measured factor which showed a change comparable with the increase in fish yield, was a change in bacterial activity in the water. This change occured when manure was applied daily. This suggests a second possible hypothesis:

HYPOTHESIS #2: Detrital Enrichment.
-That the increased fish yield in these experiments was a result of the enrichment of the manure particles by the bacteria.

Other studies suggest that the protein content of organic particles can be increased as a result of the growth of bacterial populations on them. This hypothesis needs to be tested by comparison of the protein content, or C:N ratio of suspended manure particles at closely spaced intervals after manure application.

Yang et al. (1988) and Shan and Wu (1997) show that, with animal and plant feeds respectively, the process of fermenting or composting these inputs, tends to lower fish yields. It is well known that the processs of fermenting and composting reduces the energy content of the substrate.

HYPOTHESIS #3: Detrital Energy Content.
-That in fish ponds, suspended particulate material resulting from processed (composted or fermented) materials will be lower in energy value, than paticles derived from fresh manures.

There is a need to test this hypothesis by carefully measuring the nutritional quality of feed inputs and the suspended particles which are derived from them. In the case of the green material inputs, the measurement is complicated by the fact that grass carp convert the green material into excreta which then forms the suspended particles on which silber carps feed. The energy content of equivalent weights of the green material should be measured before and after composting. The bomb calorimeter, (See equipment requirements) is designed to measure energy content of organic materials.

In summary, much more detailed attention should be given, in this study of the suspended organic matter, to the:

energy content
nutritional value
particle density
sinking rate
and bacterial enrichment

of the suspended organic particles in the fish pond.

The intensity of sampling and the precision of chemical measurements must be increased. The latter can be done by making more (3 or 4) repeated measurements on the same sample.

Water sampling should be done further away from the pond edge than is practiced now, because the closeness of the water to the pond side can have an effect on the movement of the water, and therefore on the suspension of the particles.

Samples should also be taken from different depths in the pond. Methods and equipment for sampling can be discussed when Aquaculture International delegates visit to Winnipeg in September.

This study of suspended prganic matter in the water could be multi-disciplinary, involving study groups specialized in:

water chemistry
nutrition
mathematical modelling
energy flow studies
photosynthesis and primary productivity.

2. STUDIES OF FISH FEEDING AND GROWTH OF FISHES

Yang et al (1986) show that when the input of green material to the ponds is held constant (not varying), and the weight of grass carp is also held constant, that by decreasing the weight of filter-feeding fishes, the net yield of filter feeding fishes, (and total fish yield of the pond), can be increased (Fig. 5).

HYPOTHESIS #4: Stocking Ratios.
-That a decrease in the relative weight of filter-feeding fishes reduces the rate of consumption on the phytoplankton, and this results in an increased energy input to the pond by means of increased photosynthesis.

This hypothesis implies that the "management" of primary productivity should be a goal in integrated fish farming, in addition to management of manure inputs. The light meter (See equipment requirements) is required for measurement of primary productivity.

If it can be demonstrated that the density of suspended organic particles can be controlled by the method of manure application, or by the process of manure treatment, or by water mixing processes in the pond, or by altering fish species ratios, then it raises the folowing questions:

i. What is the optimum particle density for maximum growth of silver carp? -for bighead carp? (see Fig. 6a)

ii. How does this optimum density vary for different sizes of filter-feeding fishes?

iii. How does the rate of consumption of particles vary with the size of silver carp? -of bighead carp? -with temperature?

iv. How does the rate of consumption of suspended particles by filter-feeding fishes compare with the rate of input of particles, when manure is applied once per day or once per week.

v. How much water volume does a silver carp (or bighead carp) filter in one day at a certain body size and water temperature?

vi. What is the rate of excretion of particles as a result of grass carp feeding? -at different body size?
-at different rates of supplied feed?
-at different temperatures? (see Fig. 6b).

The above questions suggest an approach to the problem of fish species ratios in a complex polyculture system. The fish ratio problem is intractable because of the large number of combinations generated by 6 fish species, and a large number of stocking sizes, stocking densities and relative densities for each species. An alternative approach is to build a model of the functional response of each species of cultured fish to its food supply, and to model the important interactions in the pond system. This objective can be stated in the form of a hypothesis:

HYPOTHESIS #5: Feeding Dynamics.
-That the growth of each fish species in a polyculture system can be modelled as a function of a few key variables, and that the growth of each species will be independent of other species.

The major variables controlling fish growth in aquaclture systems are (a) water temperature, (b) fish weight, (c) food availability, and (d) food energy content. These relationships can be determined by measuring the growth rate (instantaneous growth rate as % of body weight per day) of a given species at several different rations. A ration is the amounbt of feed or manure supplied, measured as % of the fish body weight per day. Most of the previous experiments have used a ration of 3% body weight per day to calculate the amount of manure to put into the pond. Other experiments could be done at 2%, 4%, 5%, 6%, and 7% of body weight per day.

The objective is to define a mathematical relationship between the input of feed, and the growth response of the fish. The growth need not be measured over the whole growing season. In fact, it is better if the growth can be measured over short (2 week) periods. In that way, the growth experiment can be repeated each month, when the fish are 100 g, 300 g, 500 g, and 700 g in body weight. In this way the effect of fish size can be examined separately from the other variables. The temperature must be recorded continuously, (See equipment requirements - continuous temperature recorders). The growth of individual fish must be measured (30 fish, minimum) so fish must be marked using a combination of small fin clips (cut fins).

At the sme time this experiment is taking place, it would also be useful to measure the changes in density of suspended organic particles as a result of fish feeding and manure input. In one pond, the manure could be applied, but no fish introduced, to measure the change of particle density in the absence of feeding activity. In this case, the two processes acting to change particle density will be the input rae (of manure) and the setling rate (sinking rate or falling rate) of the particles.

This type of ration study could be repeted for grass carp or Wuchang fish, varying the input of green plant material as a percentage of fish body weight. In this experiment, the rate of increase in particle density should be measured as it results from the feeding and excreting activities of the grass carp.

Some of these studies could be done in aquaria.

The study of fish feeding, like the study of suspended particles, can involve a wide number of research disciplines, such as
- -water chemistry
- -fish ecology
- -mathematical modelling
- -bacteriology
- -photosynthesis and promary productivity
- -energy flow studies

3. PHYSICAL PROCESS STUDIES

Zhang et al (1987) has shown that an increase in pond area caused an increase in the net yield of fish from the pond, particularly the filter-feeding fishes (Fig. 7). The main difference among ponds of different size is that the wind has a longer distance over which to cause water circulation in the bigger pond.

HYPOTHESIS #6: Pond Size.
-That fish ponds with a larger surface area have a greater degree of water circulation, and that this tends to keep suspended particles in suspension for a longer time so that filter-feeding fishes have more opportunity to feed on them.

This Hypothesis could be tested by measuring the degree of water circulation and the residence time of particles in suspension, in ponds of different areas.

Zhang et al. (1987) also show (Fig. 8) that the yield of grass carp increases with pond size up to an area of about 3 mu. Beyond this size of pond, grass carp yield decreases. This result is unexpected because both grass carp stocking density and green food inputs are maintained proportional to the pond surface The following hypothesis is suggested:

HYPOTHESIS #7: Spatial Scale.
-That the ratio of the "feeding area" to "pond surface area" controls the growth of grass carp. When this ratio falls too low (as with larger ponds), the growth of grass carp declines.

This hypothesis can be tested by varying the ratio of grass carp feeding area to pond surface area.

If this hypothesis is correct, it implies that in the larger ponds, all the fish do not respond to the food quickly, since it is placed in only one corner. This effect would result in a much larger variation among fish body weights in the large ponds than is seen in the 3 mu ponds. The solution to the decline in yields would be to increase the number of feeding stations for grass carp in large ponds.

Zhu et al. (1986) have also shown that an increase in the ratio of the pond water volume to the area of the pond humus, results in an increase in the net yield of filtering fishes (Fig. 9). More importantly, they show that an increase in the ratio causes a decrease in the volume of the pond humus which accumulates over the growing season (Fig . 9). This is important because pond humus is a problem for the farmers to get rid of, and the ponds become more shallow each year by several centimeters.

HYPOTHESIS #8: Pond Depth.
-That effectively increasing the height of the water which lies above 1.0 square metre of pond bottom (Fig. 10), increases the "residence time" (time which particles stay up in the water) of particles and therefore shifts the energy away from the pond humus and towards the filter-feeding fishes.

The pond humus represents a loss of energy to the filter-feeding fish. While it thought to be utilized by the bottom-feeding fishes to some degree, the yield of bottom feeding fishes does not increase in these experiments as the volume of pond humus increases. This leads to the following hypothesis:

HYPOTHESIS #9: Sediment Oxidation.
-That pond humus can only be utilized in the fish food chain when it is exposed to oxygenated water. Most of the pond humus is removed from the energy pathways in the pond by burial, which removes it from aerobic conditions.

This hypothesis can be tested by increasing the oxygen content of water at the sediment surface by artificial means, or by resuspending pond sediment periodically by pumping.

The observations which lead to hypotheses #6, #8 and #9 suggest a more general hypothesis which has far-reaching implications for pond management in polyculture systems:

HYPOTHESIS #10: Water Circulation.
-That any increase in the rate of pond water circulation or any other process that will increase the residence time of particles in the water column, (Fig. 11 shows examples), will shift the energy pathway towards the filter-feeding fishes and increase the yield of pond fish integrated fish farming ponds. At the same time, pond humus will be reduced.

The work already completed by the RLCC Pond Dynamics research group suggests that there is high potential for the testing of aeration and water circulation devices in fish ponds. At present, aeration is restricted to emergency situations where there is temporary loss of oxygen from the water. In future, emphasis should be placed on the use of aeration and water circulation as tools for routine management of fish culture conditions.

B. RESEARCH INTEGRATION

At present, no formal mechanism exists for integrating the large **Economic Survey** being carried out by the Economics Department, and the **Pond Dynamics Research** being carried out by the Integrated Fish Farming Research Centre. This is a serious deficiency which should be addressed as soon as possible. Closer integration of the research of these two groups at an early stage will result in much more rapid and more useful development of the science and technology associated with integrated fish farming.

Currently, the economic survey is gathering existing biological and technological information about integrated fish farms, as well as information about the social, economic and management systems in which they are imbedded. The pond dynamics research, on the other hand, is working towards a basic scientific understanding of how the pond system works. As that understanding is achieved, new technologies will be developed.

A new, formal mechanism is required which will:

(a) ensure that the pond dynamics research is guided by problems disclosed by the economic survey research.

(b) provide a means for biological research and technological development to be translated into practical applications under actual farm conditions.

(c) allow new technologies to be adapted to existing social, economic and farm management systems and vice-versa, using the full range of regional conditions upon which the economic survey is based.

Some examples of the questions raised by the economic survey are as follows.

1. Fingerling Proportion Problem.
What is the correct proportion of fingerlings of each species and

what are the correct sizes and densities of each, to achieve optimum production?

2. Silt Deposition Problem.
How to reduce silt deposition in the fish ponds and channel this energy into the fish production cycle?

3. Optimum Input Balance Problem.
Given a certain target in terms of production, and a certain stocking regime, how many pigs, ducks, chickens, cows etc. should be integrated with the fish, and how many mu of grass, crops, mulberry etc. need to be cultivated to support this level of production?

4. Grass Problem.
How to quantify the food-chain pathway which results when grasses or vegetation are put into the ponds? How can the relationships be expressed quantitatively so that farm managers can use them?

5. Manure Problem.
In quantitative terms, what is the value of each type of manure, and what management rules should be applied to the use of each?

6. Aeration Problem.
At present, aeration is used only as an emergency measure to stop fish from dying. What is the cost/benefit of using different aeration strategies for the improvement of water quality?

7. Marginal Analysis Problem.
How does profit vary as a function of production? Higher profits may be the goal of pond managers, rather than higher production.

A number of these questions are already being addressed by the pond dynamics research group, and considerable progress has been made under the first IDRC research grant. The objective of the pond dynamics group should continue to be basic scientific research, using these practical problems as a guide for research direction.

What will be required soon, is a means of translating some of the reasearch results into practical technology. For example, research results from a number of the pond dynamics projects (studies of the effects of pond area and pond depth) already suggest that water circulation might be important for increasing yields. If this can be experimentally confirmed by the pond dynamics group, the next step would be to develop and test prototype technology to create water circulation in fish ponds. This type of experimentation should also be carried out by the pond dynamics research group.

However, a further step would be to test this technology under real fish farm conditions on a pilot scale. Perhaps this could be the role of the ten test ponds operated by the economic survey group. These ponds differ from the experimental ponds of the IFFC pond dynamics group in that they are located in different geographical regions of the country, and they are operated by fish farmers in an economic context.

The testing of new technologies on real fish farms which operate under different economic, social and farm management regimes would give valuable insights into the process of technological adaptation.

V. RECOMMENDATIONS

A. RESEARCH MANUSCRIPTS

Every effort should be made to publish the six manuscripts associated with the IDRC-sponsored pond dynamics research poject.

All will require English language revision and statistical analysis of data. Assistance can be obtained from journal editors and from English-speaking colleagues.

B. ON-GOING RESEARCH

Specific suggestions for each of the pond dynamics research projects may be found under III PROJECT REVIEW, A. Review of pond dynamics projects. A draft of this report, containing all of the suggestons, was left at the Freshwater Fisheries Research Centre in Wuxi in May, 1988, so that there would be an opportunity to implement some of them during the 1988 fish-growing season.

Planning for how data will be analysed statistically, should be done prior to actual research.

Pond humus should be considered an important "yield" from the ponds, and measured accurately at the end of each pond experiment.

Primary productivity is an important energy source to the ponds and shoud be measured in each experiment.

Manure inputs should be characterized in considerably more detail as they constitute the major inputs to the ponds.

Preparation of fermented and composted manure inputs should be standardized to take seasonal differences in temperature into consideration.

C. STAFF UPGRADING

English language training should be a priority for Chinese scientists. This should begin with the study of English while in China so that proper use can be made of study leave abroad.

Chinese scientists should be sent for six months to one year to English-speaking research laboratories, in order to obtain English language training and technical training in their area of specialization.

Training in statistics is also a priority. This could be best accomplished by having two, one-month courses in statistics taught in China.

Several areas of technical training are considered to be useful in the study of integrated fish pond dynamics. These are:

- Quantitative analysis in aquaculture
- Microbiology
- Limnology
- Computer technology

This technical training should be obtained by study leave in foreign laboratories.

D. EQUIPMENT REQUIREMENTS

Several pieces of major equipment should be purchased to support pond dynamics research. This equipment is specifically for data analysis, and for measurements of fish food energy content, primary productivity, and water circulation in fish ponds.

A number of expendable supplies should be purchased to support the pond dynamics research. These are supplies which are impossible or very difficult to obtain within China.

E. NEW RESEARCH

Three areas for new research are identified, studies of:

(a) suspended organic matter,

-focuses attention on the sources of food in the fish pond systems, including material produced within the pond by algal growth, and material introduced into the pond such as vegetable and animal manures, and feeds.

(b) food and feeding of fishes

-focuses attention on energy pathways and feeding interrelationships among the major fish species in the pond system.

(c) physical processes

-focuses attention on some of the physical driving forces in pond productivity, such as the role of water circulation in suspending particles, and in delivering oxygen to the pond sediments.

Consideration should be given to orienting new research projects around these themes. Each theme is broad enough to embrace a number of reserch disciplines.

Some of the pond dynamics experiments can be repeated, but with the emphasis shifted so that measurements test specific hypotheses to explain the reason for observed results. A number of hypotheses have been suggested as examples.

F. RESEARCH INTEGRATION

Pond dynamics research must be guided by practical problems in the management of integrated fish farms. A number of these problems have been defined by the Economic Survey.

When the results of basic research suggest new technologies, these technologies must be tested under experimental conditions by the pond dynamics research group.

Once new technologies appear to be feasible, they should be implemented on a trial basis under actual fish farm conditions, and monitored carefully regarding success or failure.

A formal mechanism is required to integrate the work of the Integrated Fish Farming Section and the Economic Survey Department.

VI ITINERARY

APR 19	Depart Canada, arrive China via Vancouver and Shanghai.
APR 20 AM	Tour of Shanghai Fisheries University, Aquaculture Department, Electron microscope, water chemistry labs.
PM	Depart for Wuxi.
APR 21 AM	Discussions with Mr. Guo Xia Zhen, Director, FFRC and IFFC, regarding objectives of program review.
PM	Meeting, Mr. Guo Xian Zhen, Chair, Mr. Hu Bao Tong Mr. Zhang Jian Seng Mr. Shi Wen Lei Mr. Zhang Lai Fa Mrs. Fang Ying Xue Mrs. Zhu Yun Mr. Shan Jian Mr. Yang Ye Jin Discussed objectives of program review. Presented lecture on intensive culture of walleye in Canada. Informal discussion with Mr. Guo Xian Zhen, M. Zhang Lai Fa, Mr. Yang Ye Jin, Mrs. Zhu Yun, and Mr. Zhang Jian Seng about the format for the program review. Examine FFRC Library.
APR 22 AM	Review and discussion of work with Mrs. Fang Ying Xue.
PM	Review and discussion of work with Mr. Yang Ye Jin.
APR 23 AM	Review and discussion of work with Mrs. Zhu Yun.
PM	Inspected fish ponds near FFRC laboratory.
APR 24 PM	Tour of Heili Fishfarm. Discussions with Dr. Brian Davy, Dr. Richard Arthur.
APR 25 AM and PM	Sat as observer at meetings between I.D.R.C. and F.A.O./N.A.C.A. officials, and FFRC staff.

APR 26	AM	Review and discussion of work with Mr. Zhang Lai Fa
	PM	Review and discussion of work with Mr. Shan Jian, and Mrs. Fang Xiu Zhen.
APR 27	AM	Worked on Report.
	PM	Review and discussion of work with Mr. Ding Jie Yi.
APR 28	AM	Reviewed Bioeconomic Survey
	PM	Discussion with Mr. Chen Guan Seng regarding objectives of the economic survey and its integration with IFFC work.
APR 29	AM	Discussion with Mr. Zhang Jian Seng and Mr. Zhang Lai Fa concerning the proposal for future research to be funded by IDRC.
	PM	Worked on report.
APR 30	AM	Tour of the IFFC experimental fish farm with mrs. Zhu Yun and Mr. Zhang Lai Fa. Tour of Fish Nutrition and discussion of work with Mr. Shi Wen Lai.
	PM	Worked on report.
MAY 1	AM	Labour Day Holiday. Worked on report.
	PM	Tour of Lake Taihu by FFRC motor boat.
MAY 2	AM	Meeting at IFFC laboratory with Mr. Zhang Jian Seng, Mr. Zhang Lai Fa and Mrs. Zhu Yun. Tour of Fish Genetics and discussion of work with Mr. Zhang Jian Seng. Discussion of future research proposal.
	PM	Tour of the Tawan BAy experimental Fish Farm.
MAY 3	AM	Write Project Reviews and Recommendations for new project proposal.
	PM	Meeting with Mr. Guo Xian Zhen and all of project leaders. Present lecture on my perspective of integrated fish farming. Deliver project recommendations and discuss new approaches to integrated fish farming research.

MAY 4	AM	Copy all project reviews and proposal recommendations for use by FFRC staff.
	PM	Depart for Shanghai.
May 5	AM	Discuss integrated fish farming research with Prof. Li Sifa, Shanghai Fisheries University.
	PM	Prepare lectures.
MAY 6	AM	Present two lectures: (a) Feeding behaviour of walleyes as applied to intensive culture. (b) An overview of salmon pen culture on the west coast of Canada.
	PM	Depart Shanghai, Arrive Manila.
MAY 7	AM	Discussion with Dr. Chua Thia Eng, ICLARM.
	PM	Discussion with Mr. J. McLean, Editor, ICLARM.
MAY 8	PM	Holiday. Tour Manila.
MAY 9	AM and PM	Visit ICLARM offices, meet Director and research staff.
MAY 10	AM	Depart Manilla, Arrive Vancouver.
MAY 11	AM and PM	Arrange scientific contacts for Chinese delegation to Aquaculture International Conference in Sept. 1988.
May 12	AM	Depart for Winnipeg.

FIGURES

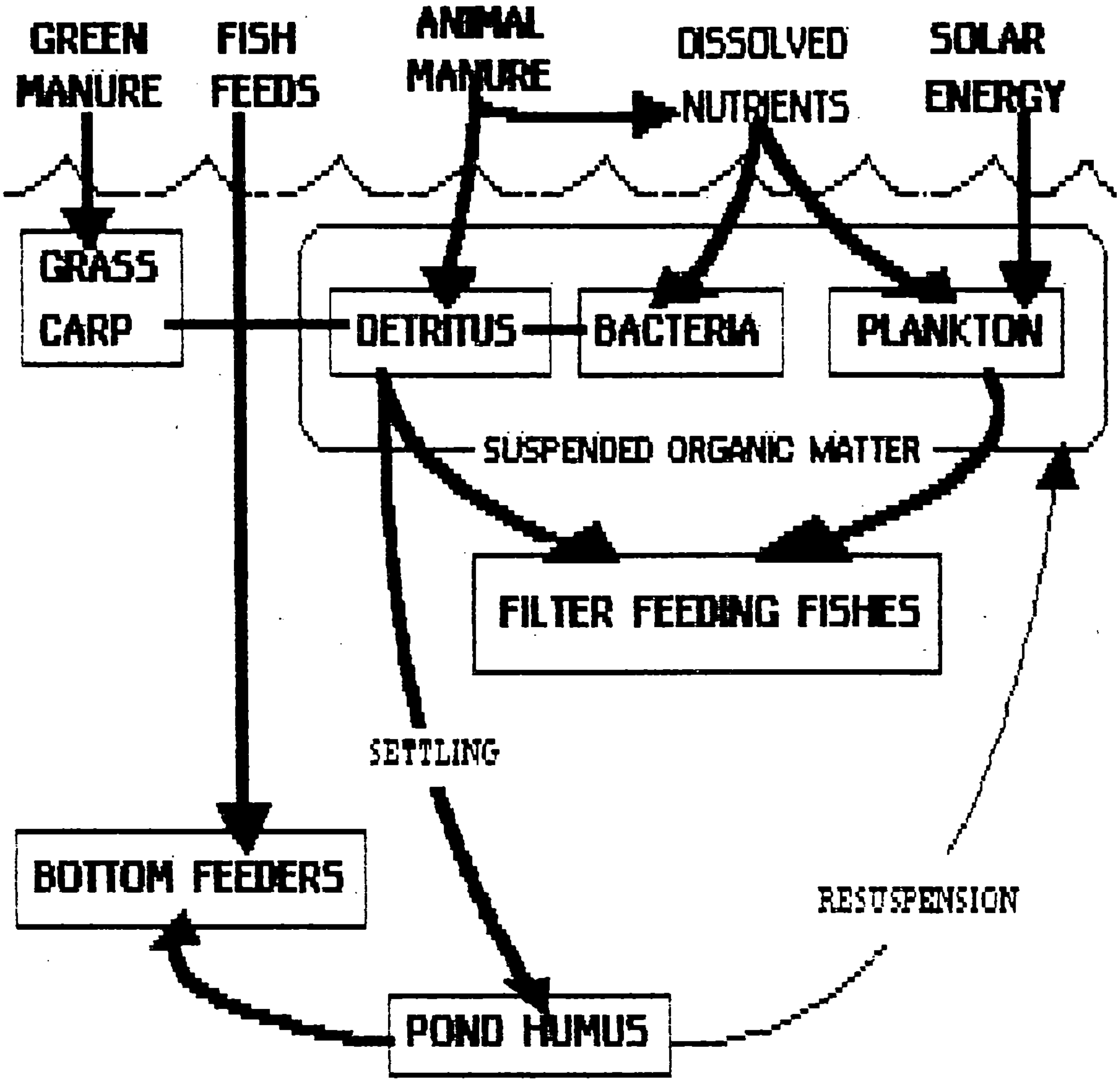

GREEN MANURE
FISH FEEDS
ANIMAL MANURE
DISSOLVED NUTRIENTS
SOLAR ENERGY
GRASS CARP
DETRITUS
BACTERIA
PLANKTON
SUSPENDED ORGANIC MATTER
FILTER FEEDING FISHES
SETTLING
BOTTOM FEEDERS
RESUSPENSION
POND HUMUS

FIG. 1

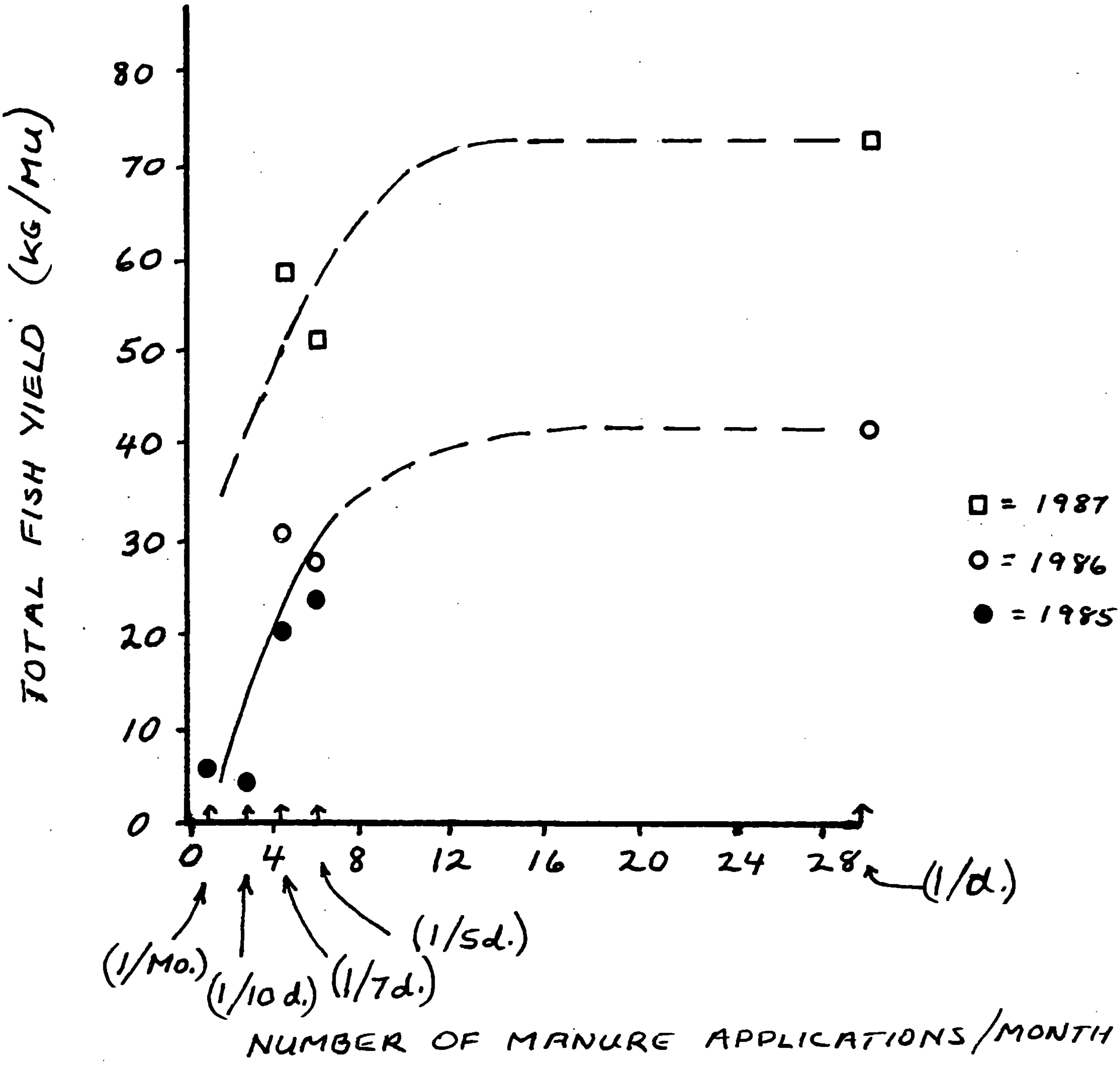

TOTAL FISH YIELD (KG/MU)
80
70
60
50
40
30
20
10
0
0
4
8
12
16
20
24
28
(1/Mo.)
(1/10 d.)
(1/7d.)
(1/5d.)
(1/d.)
□ = 1987
○ = 1986
● = 1985
NUMBER OF MANURE APPLICATIONS/MONTH

FIG. 2.

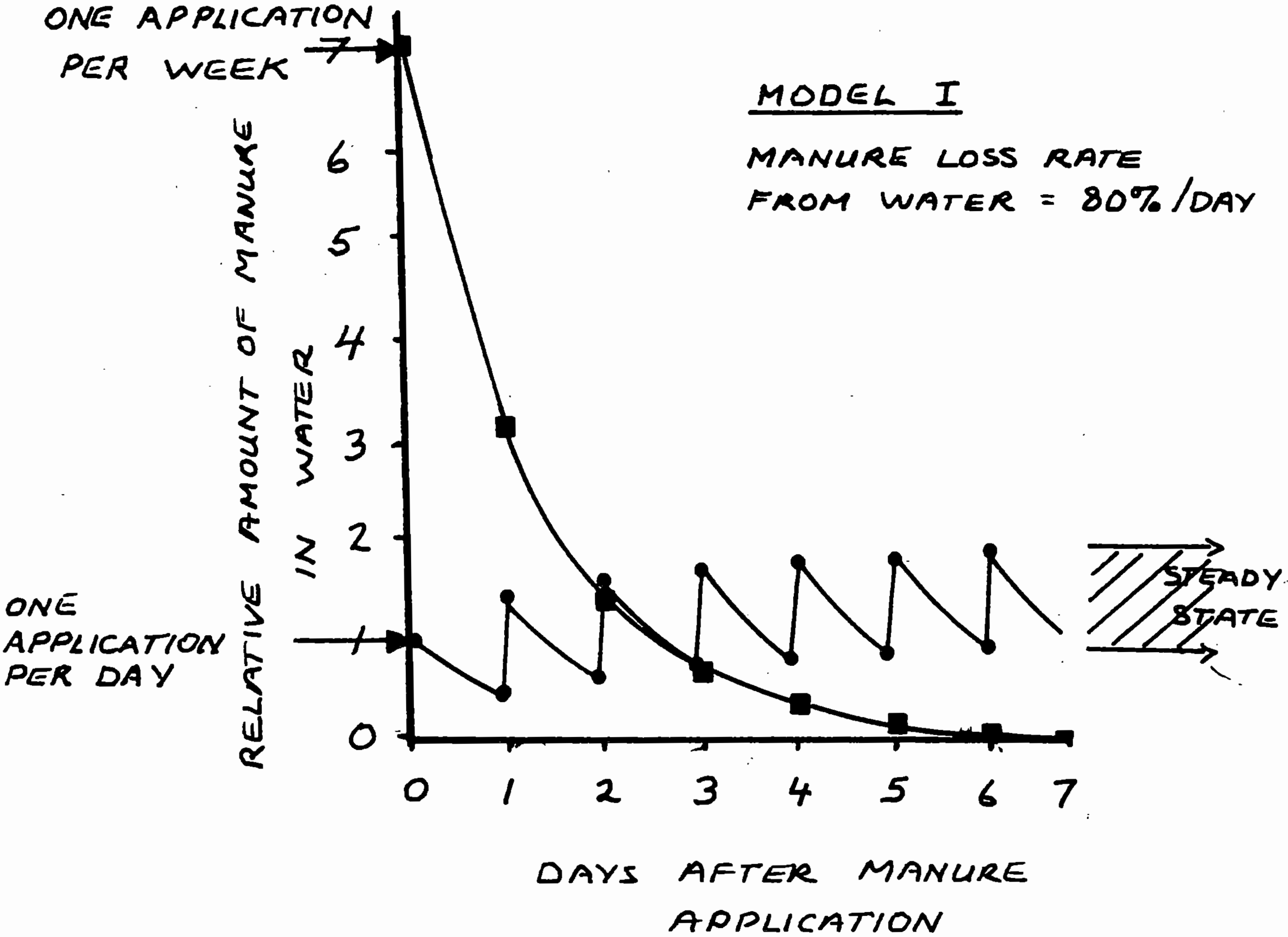
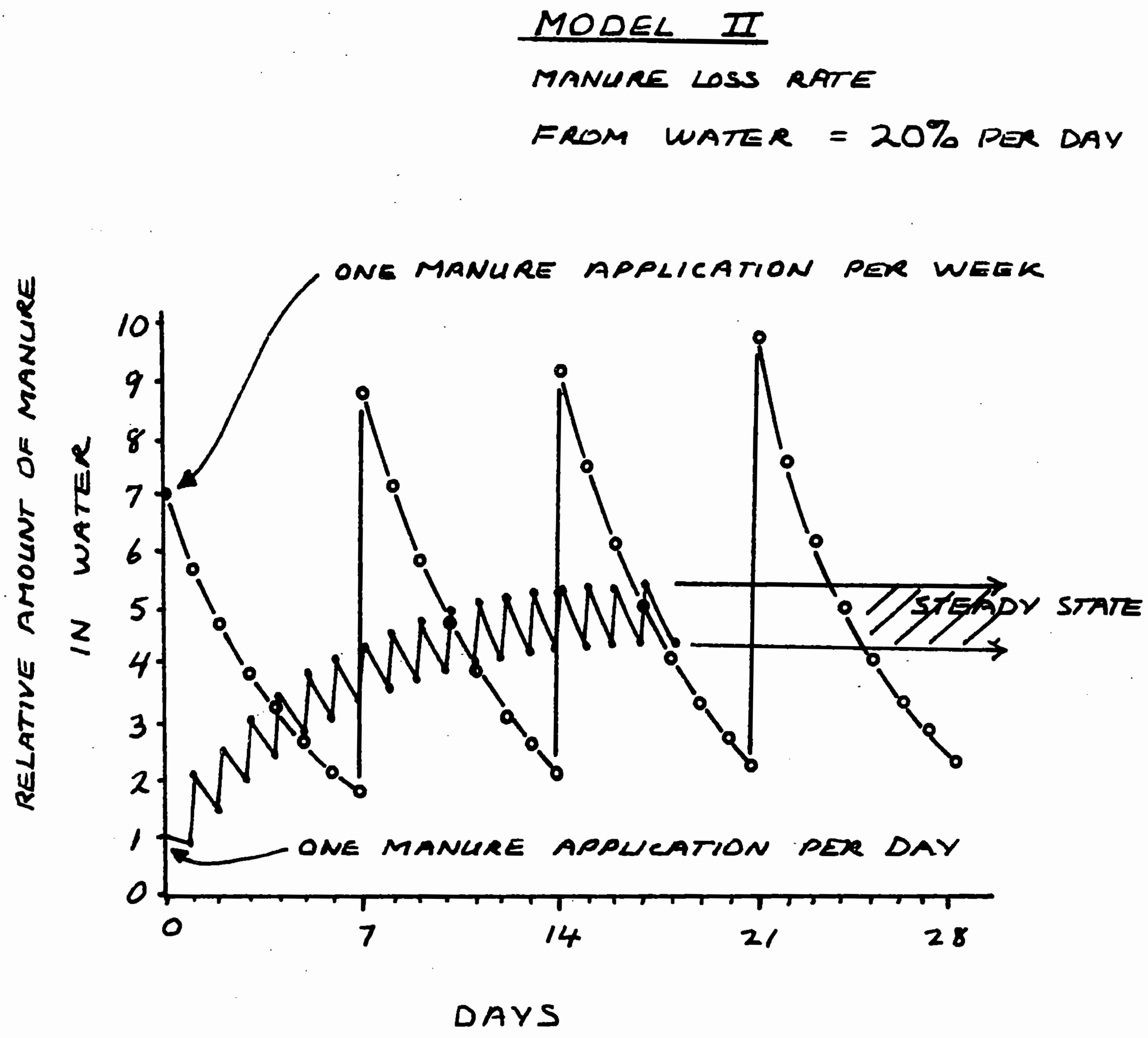
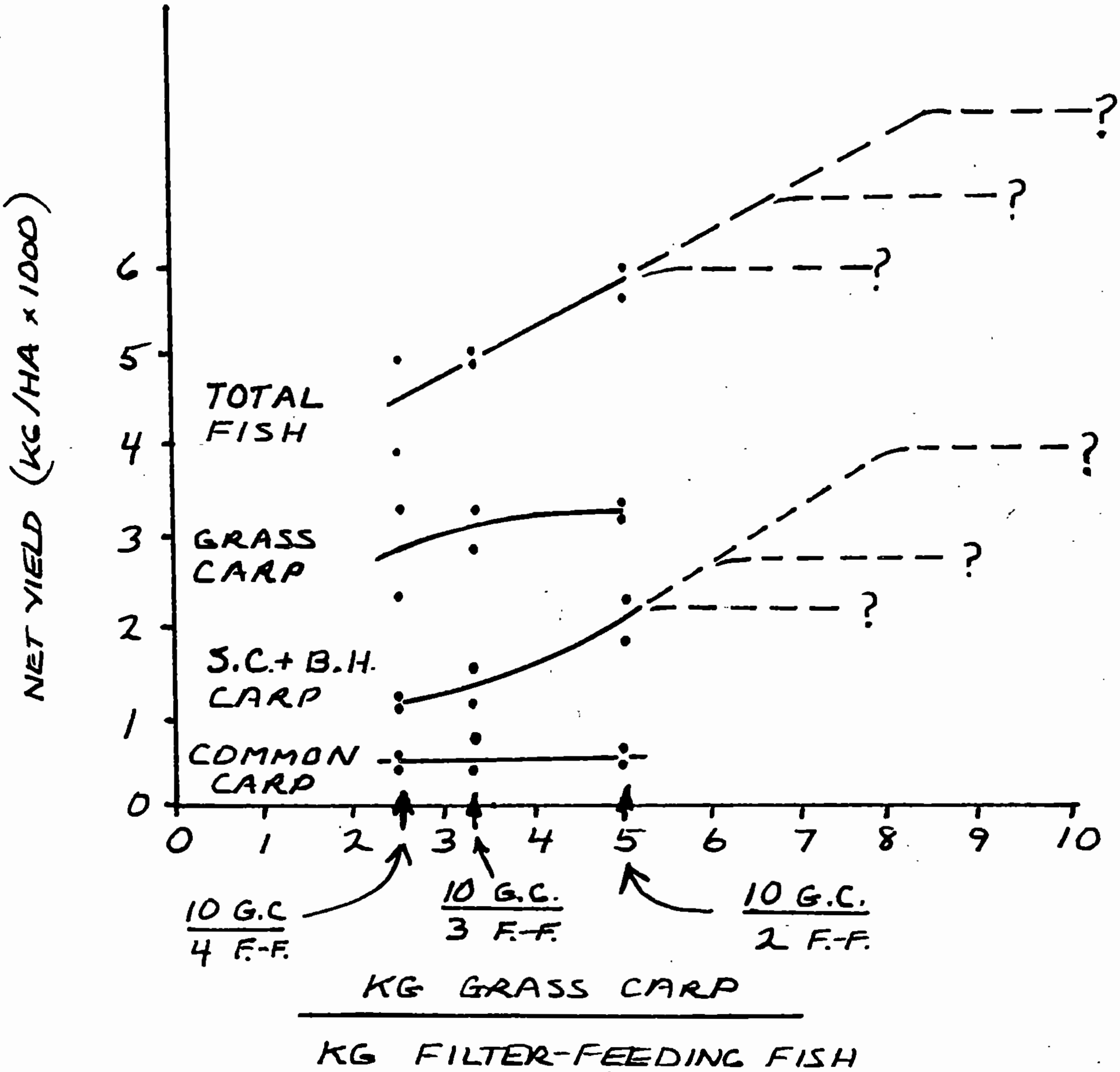

ONE APPLICATION PER WEEK
ONE APPLICATION PER DAY
MODEL I
MANURE LOSS RATE FROM WATER = 80% /DAY
RELATIVE AMOUNT OF MANURE IN WATER
STEADY STATE
0
1
2
3
4
5
6
7
DAYS AFTER MANURE APPLICATION

FIG. 3



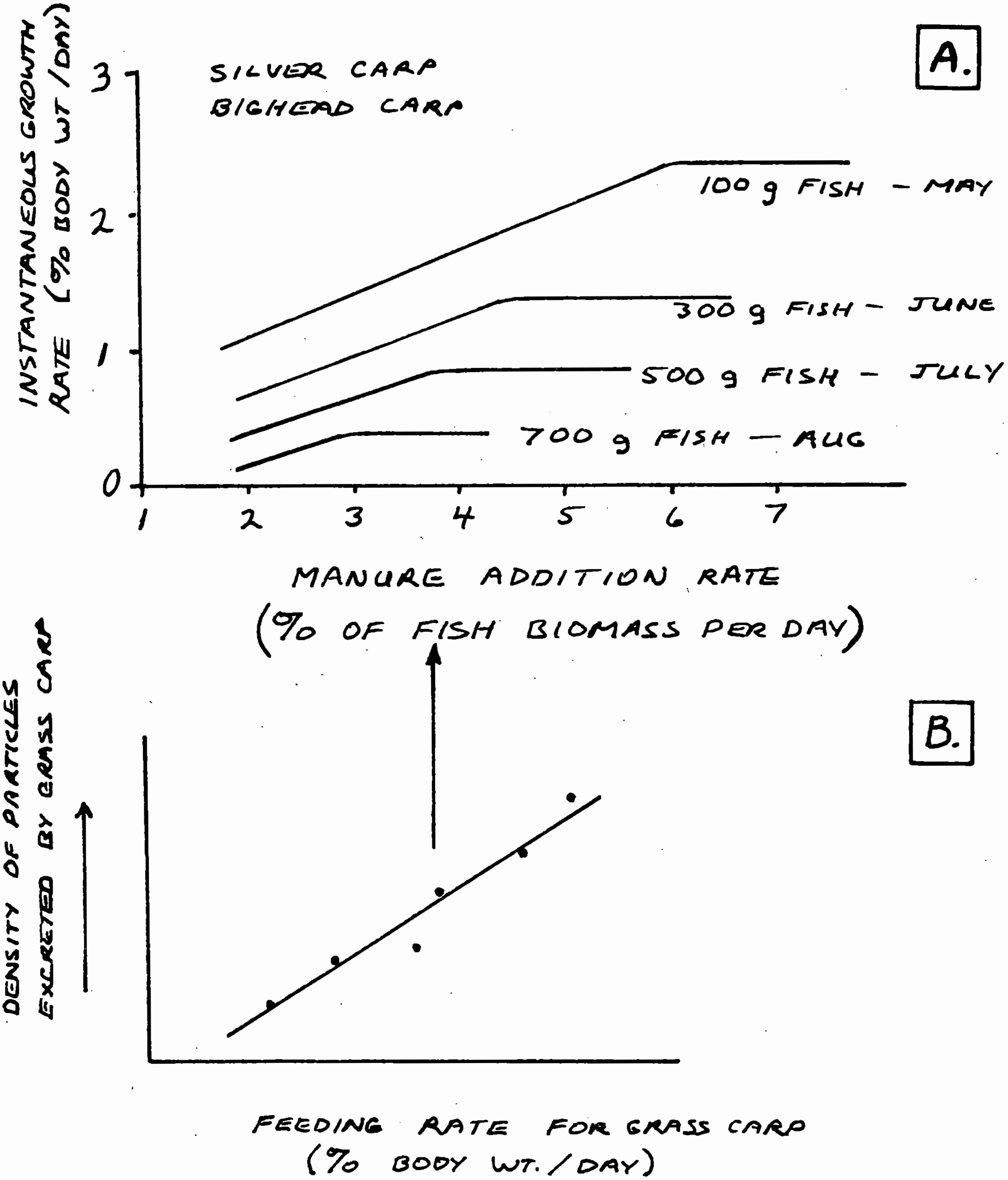
MODEL II
MANURE LOSS RATE
FROM WATER = 20% PER DAY
ONE MANURE APPLICATION PER WEEK
RELATIVE AMOUNT OF MANURE
IN WATER
10
9
8
7
6
5
4
3
2
1
0
STEADY STATE
ONE MANURE APPLICATION PER DAY
0
7
14
21
28
DAYS

FIG. 4



NET YIELD (KG/HA x 1000)
6
5
4
3
2
1
0
TOTAL FISH
GRASS CARP
S.C.+ B.H. CARP
COMMON CARP
?
0
1
2
3
4
5
6
7
8
9
10
10 G.C / 4 F.-F.
10 G.C. / 3 F.-F.
10 G.C. / 2 F.-F.
KG GRASS CARP / KG FILTER-FEEDING FISH

FIG. 5



A.
INSTANTANEOUS GROWTH RATE (% BODY WT / DAY)
SILVER CARP
BIGHEAD CARP
100 g FISH – MAY
300 g FISH – JUNE
500 g FISH – JULY
700 g FISH – AUG
0
1
2
3
1
2
3
4
5
6
7
MANURE ADDITION RATE
(% OF FISH BIOMASS PER DAY)
B.
DENSITY OF PARTICLES EXCRETED BY GRASS CARP
FEEDING RATE FOR GRASS CARP
(% BODY WT. / DAY)

FIG. 6.

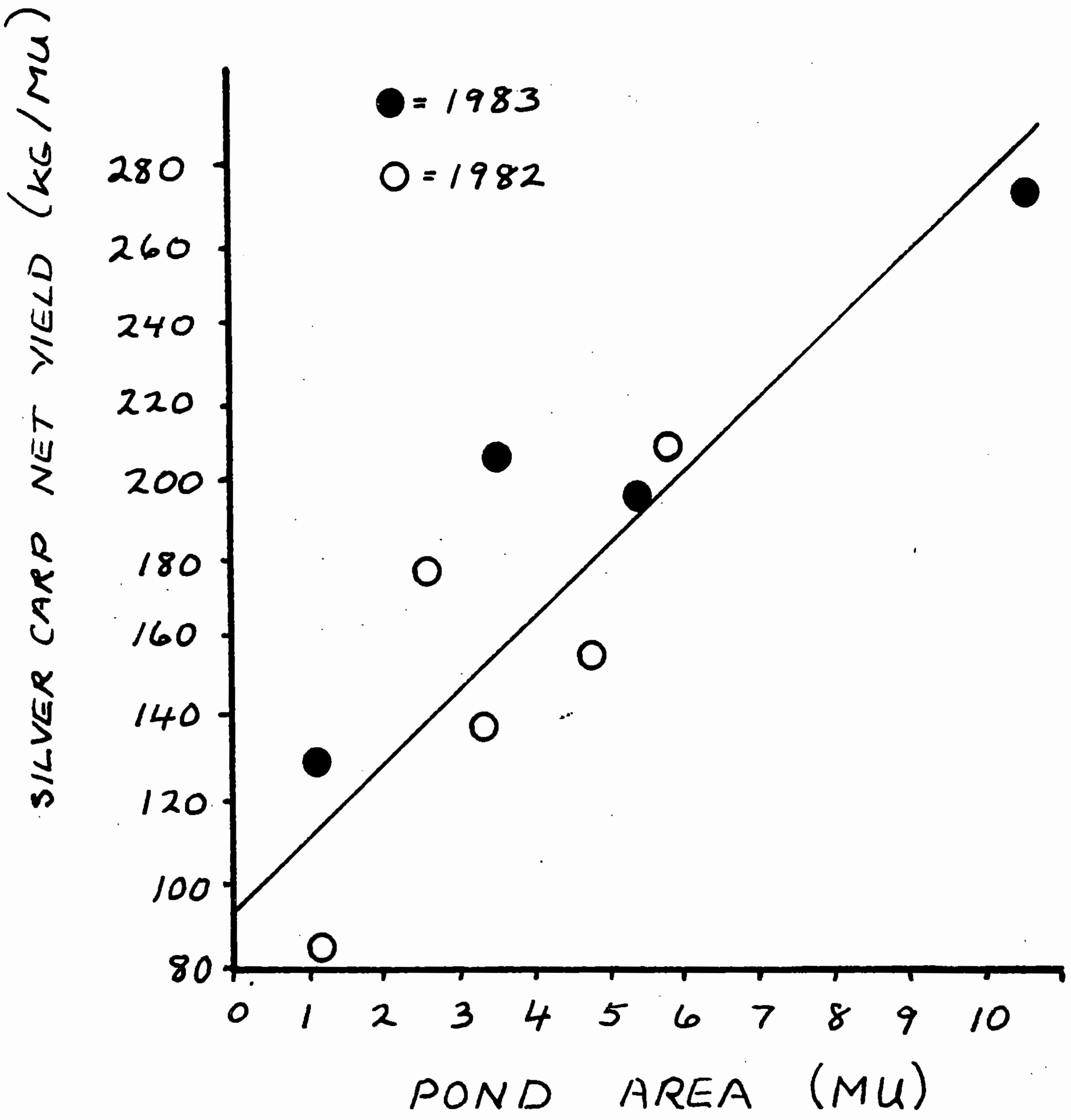

● = 1983
○ = 1982
SILVER CARP NET YIELD (KG/MU)
280
260
240
220
200
180
160
140
120
100
80
0
1
2
3
4
5
6
7
8
9
10
POND AREA (MU)

FIG. 7

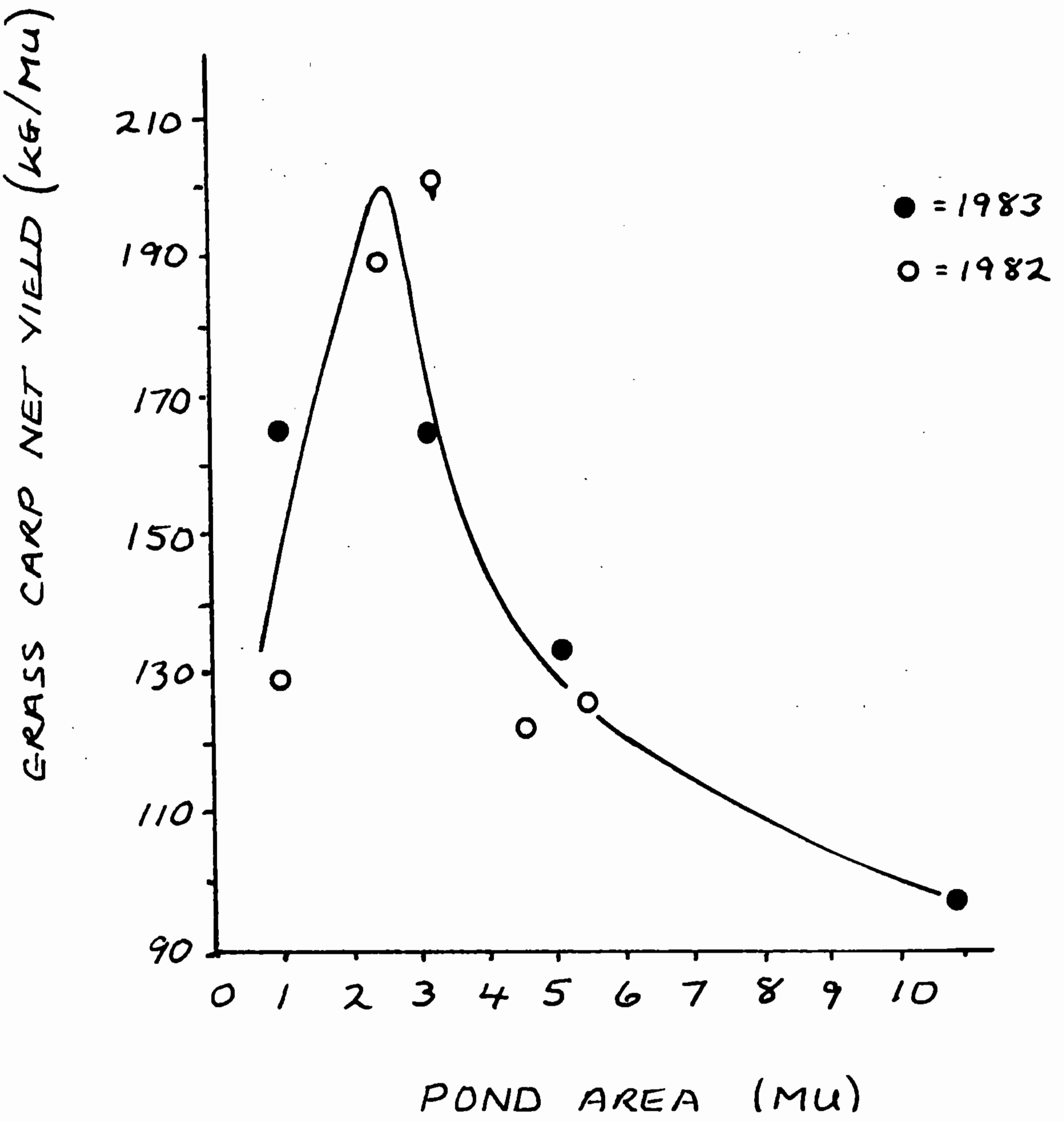
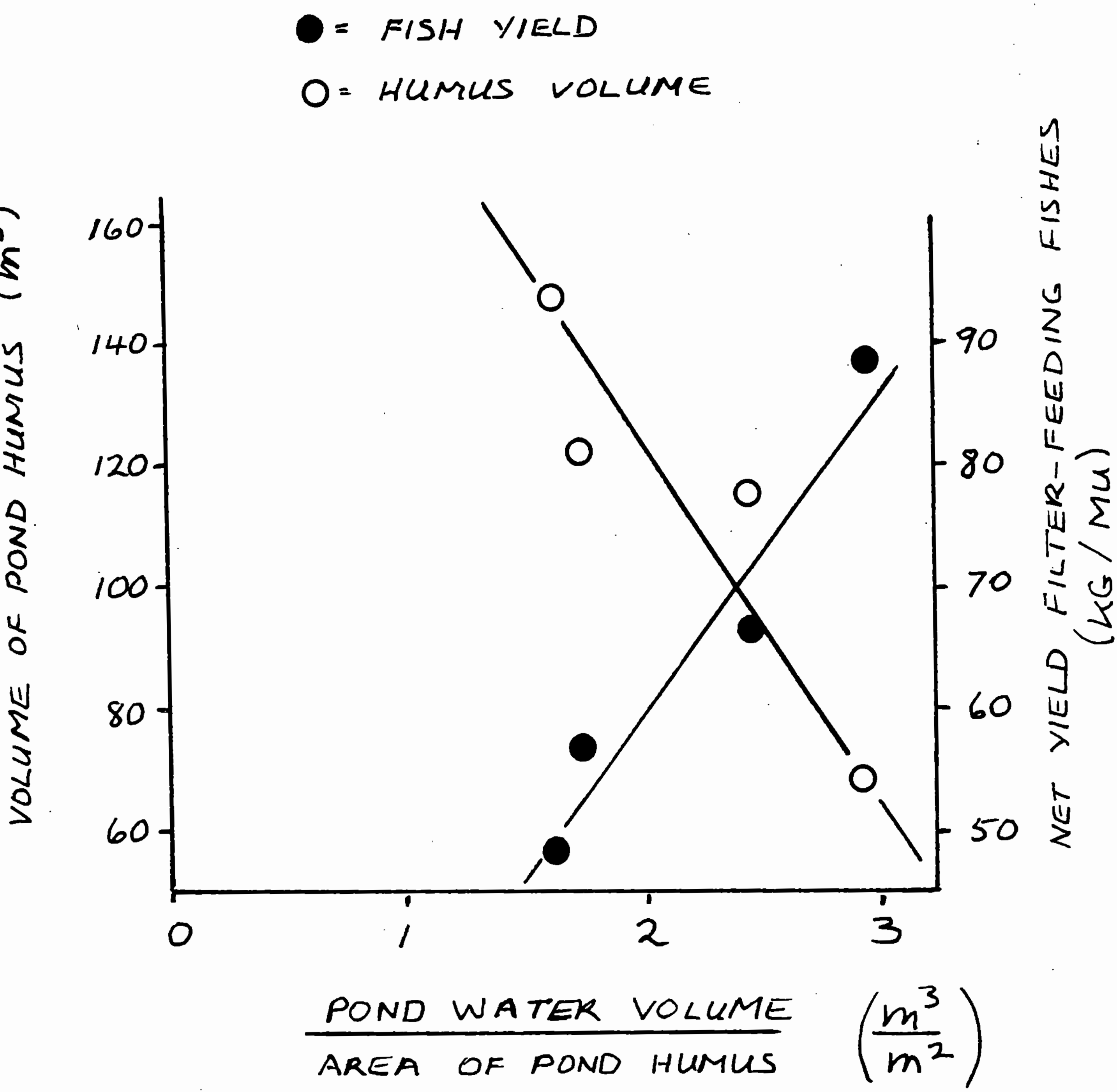

GRASS CARP NET YIELD (KG/MU)
210
190
170
150
130
110
90
● = 1983
○ = 1982
0 1 2 3 4 5 6 7 8 9 10
POND AREA (MU)

FIG. 8



● = FISH YIELD
○ = HUMUS VOLUME
VOLUME OF POND HUMUS (m^3)
160
140
120
100
80
60
NET YIELD FILTER-FEEDING FISHES (KG/MU)
90
80
70
60
50
0
1
2
3
POND WATER VOLUME / AREA OF POND HUMUS ($\frac{m^3}{m^2}$)

FIG. 9.

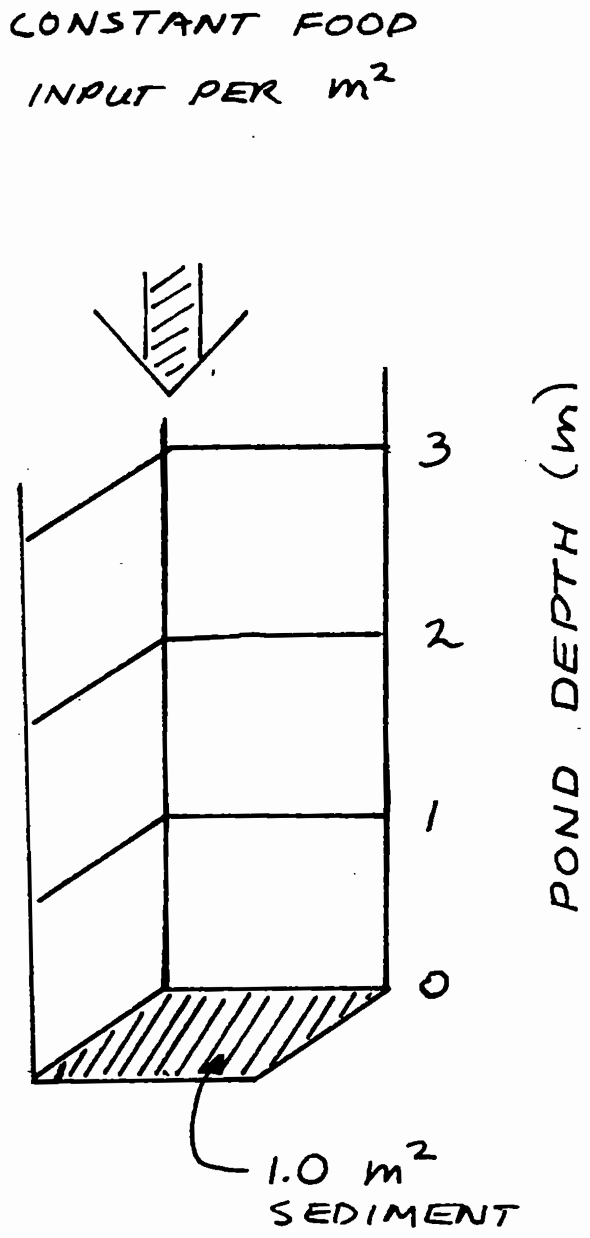


FIG. 10

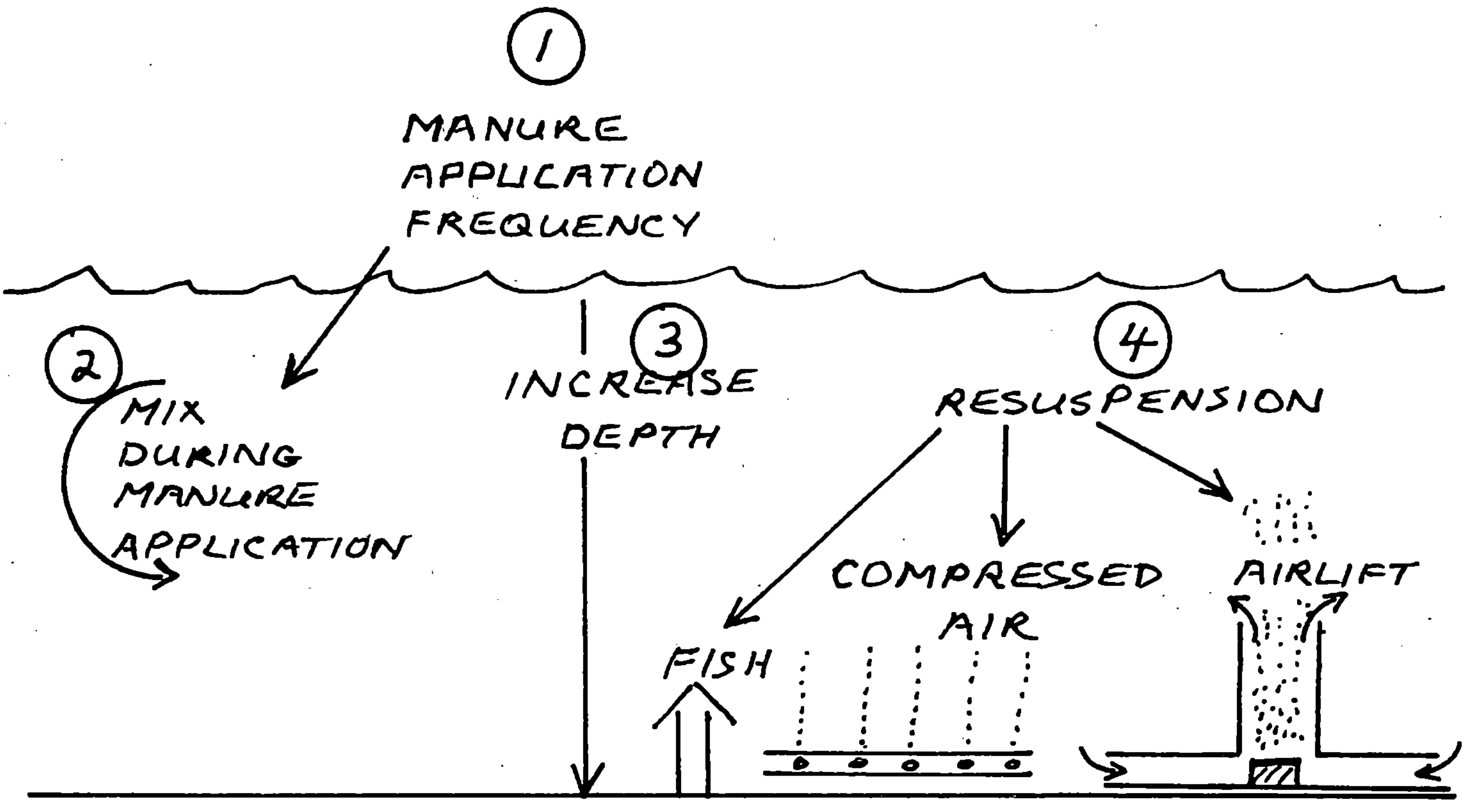

1
MANURE
APPLICATION
FREQUENCY
2
MIX
DURING
MANURE
APPLICATION
3
INCREASE
DEPTH
4
RESUSPENSION
COMPRESSED
AIR
AIRLIFT
FISH

FIG. 11